
Space Weather Technical Forecast

Issued on Saturday, 24 December 2022 at 12:43 Local

This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales <https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales>

Space Weather Forecast Headline: Potential Earth-directed CMEs - cursory analysis suggests arrival Monday 26 December and perhaps midweek. Risk G1 peaking 26 December, perhaps G2.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity, as measured by GOES16, was Low over the 24 hours, with the peak X-ray flare observed being a C6.6 at 23/1446UTC from AR3171. This sunspot region was an otherwise relatively stable group in the northern solar hemisphere, approaching the meridian as a α /Beta. Perhaps the most notable feature of this group has been its reversed polarity (its leader is negative), and its forming a near-continuum magnetically with the larger AR3169 to its west. AR3169 itself saw significant growth and proliferation in its trailing spots to finish the period as an Fsi/Beta. AR3169 group produced the two other middle-ranking C-class flares of the period, discussed below as possible progenitors of CMEs. The above were two of five numbered sunspot regions on the disc, although the remainder were magnetically less complex, stable, and unproductive in terms of X-ray flares.

The past 24 hours have been eventful in terms of potential Coronal Mass Ejections (CMEs), and the remainder of this section discusses this.

Ongoing at the start of the 24 hours around 23/1200UTC, was a large filament eruption from the southwest quadrant. Along with a prominence eruption seen around 23/1900UTC from the northeast limb, both events have been analysed and are considered misses, leading and lagging the Earth's position in its orbital path respectively. Around 23/2330UTC, a disappearing solar filament was then observed near the solar meridian in the southern solar hemisphere. A tentative analysis has been attempted based on limited imagery close-in on Lasco C2, with some hints of grazing incidence possible in some MOSWOC Enlil ensemble members on 28 December. This will be re-analysed should imagery improve.

Potentially the most noteworthy event of the 24 hours then occurred at 24/0230UTC in an eruptive filament in the northeastern disc - an impulsive emission that was subsequently visible on both Lasco and STEREO COR2. At least some of the ejecta appears to be directed centred north and east of the Sun-Earth line, however the shock at least intersects the solar meridian, and an Earth-directed component is considered likely.

The final event(s) noted in the period were a disappearing filament near the northern crown at 24/1100UTC and possible ejecta emerging from the leading spot of AR3169 at 24/0400UTC and again at 24/0800UTC, tied to impulsive mid-ranking C-class X-ray flares. There is not yet any confirmatory imagery of CMEs from any of these events, with monitoring ongoing.

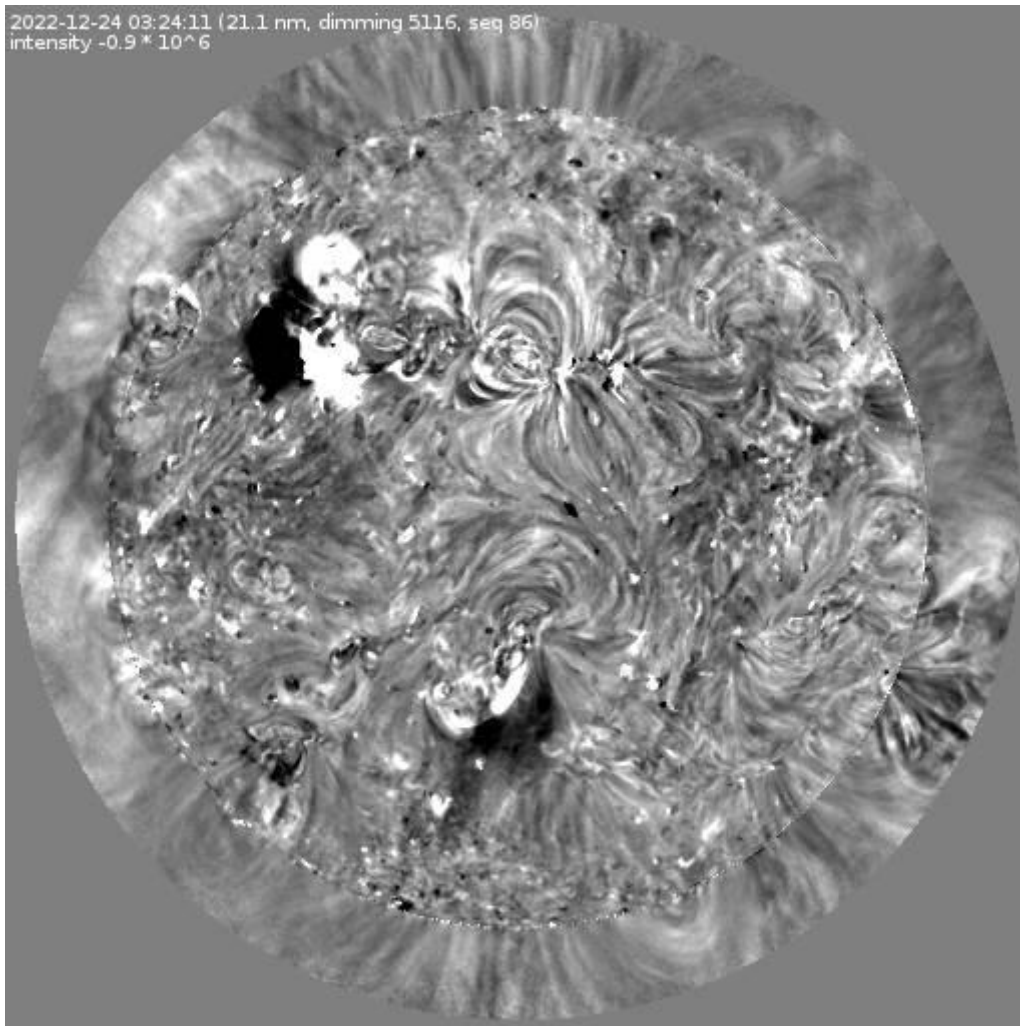


Figure 0: AIA211 time-integrated image to 24/0324UTC of footprints of two disappearing filaments of interest – firstly the south centre disc eruption 23/2330UTC; and secondly the northeast disc 24/0230UTC event. Of these, the latter is considered the greater risk for geomagnetic activity, perhaps due on 26 December, with its compatriot perhaps a lesser glance on 29 December. Image processing courtesy of SIDC ROB.

Solar Wind / Geomagnetic Activity: Solar winds, as measured at L1 by ACE and DSCOVR, followed an intensifying fast regime, most likely that emanating from CH56/+, with the phi angle correspondingly positive (away from the Sun) throughout.

Solar wind speeds increased through Elevated levels: from around 500km/s to reach 575km/s. The solar wind density was a little above the long-term average in mid-teens ppcc at peak, while the IMF was also Slightly Elevated at 11nT peak mid-period, only beginning to wane as the UTC morning of 24 December evolved. The north-south component varied between -10 and +8nT with an erratic tendency, and no prolonged aligned or anti-aligned periods (with Earth's field).

The net effect of the above solar wind measures was a provisional peak of Kp '5-' Minor Geomagnetic Storm G1 conditions in the 12-15UTC interval, with a belated possible revision upwards to 5- in the 21-24UTC interval. Activity was otherwise volatile between Quiet and Active throughout.

Energetic Particles / Solar Radiation: The high energy proton flux (greater than 10MeV) as measured at GOES16 remained at Background levels.

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High energy electron flux (greater than 2 MeV), as observed by GOES16, was at mostly Background levels, rising around period's end into Moderate flux around 400pfu. The associated 24-hour fluence continued below Active ($1e8$ integrated pfu), with a rising trend and an observed fluence at 24/0001UTC of $1.53e6$ integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Solar activity carries a now-increased Chance of M-class flares throughout the forecast period, mainly due to developments in AR3169.

Solar Wind / Geomagnetic Activity: Confidence in the geomagnetic forecast is lower than average due to changes due to the number of possible transients and because of changes to upcoming coronal holes between passes.

In terms of CMEs, there is a pre-existing small chance of marginal interaction with a CME on the remainder of day one, 24 December. This CME originated on 21 December.

The CME picture is otherwise in a state of flux, and keeping abreast of the forecast is advised. There are now two other points of note: firstly and most significantly is the 24/0230UTC northwest quadrant eruptive filament. Early analysis of this event suggests interaction with at least the shock and very possibly the core of the CME on 28 December. This is likely to result in the peak geomagnetic activity for the four days, probably G1 Minor Storm and perhaps G2 Moderate. A second, slower and lower confidence event in the form of a disappearing filament from the south centre 23/2330UTC may then give marginal effects outside the coming four-day period on 29 December. This latter event will be re-analysed should improved imagery become available.

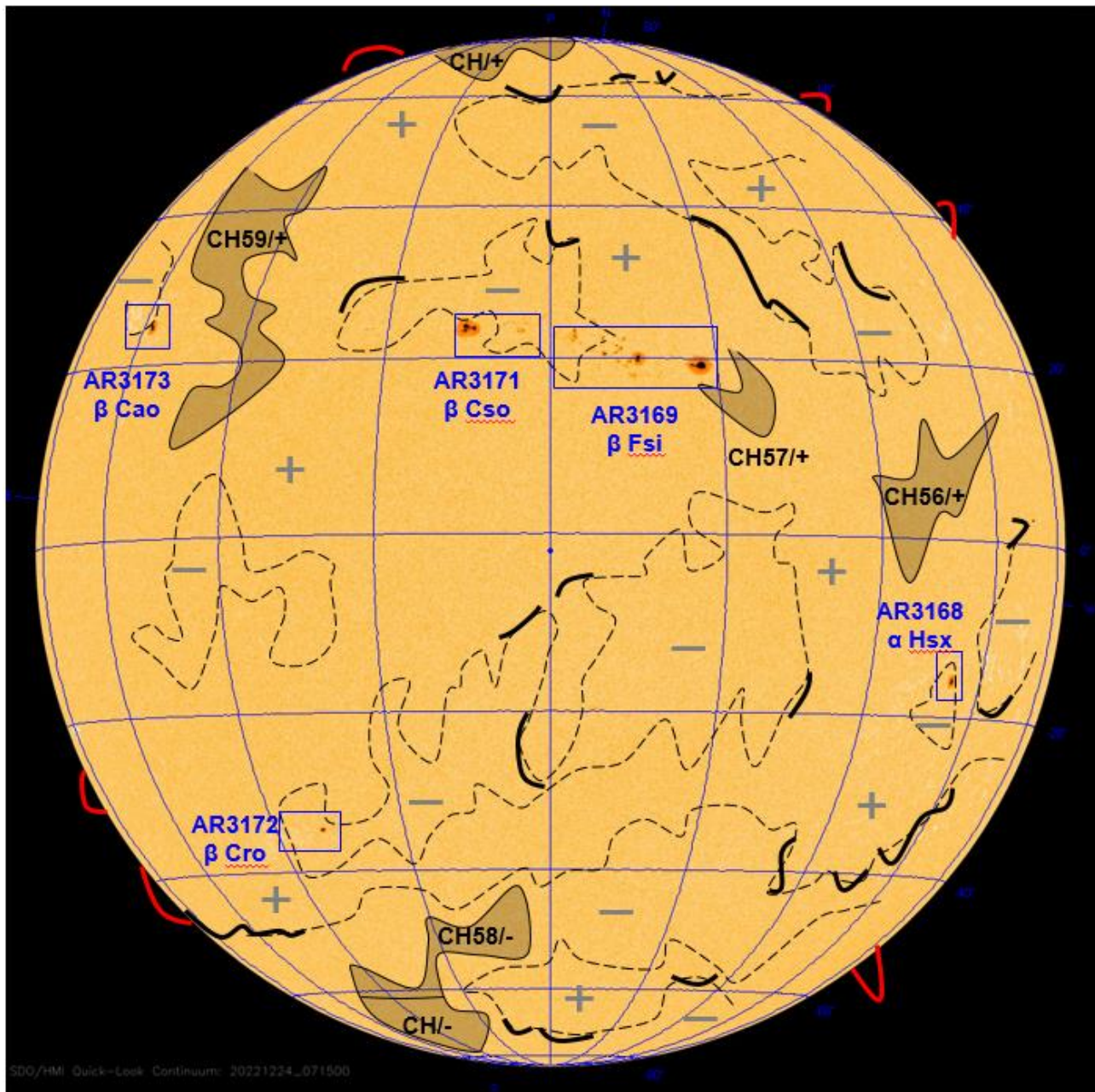
Solar winds are otherwise forecast to be Slightly Elevated or Elevated through the period due to ongoing fast winds, initially from CH56/+, but with a further enhancement likely from CH57/+ day 3 or day 4 (Monday 26 or Tuesday 27 December).

The combination of all the above factors should result in a disturbed geomagnetic environment throughout, probably showing two peaks: both in the immediate term and again on Monday 26 December. The larger risk is Monday's peak, with a Chance of G2, else Likely G1. G1 is also rated a Chance for the remainder of day one, Saturday 24 December, and in the aftermath of any CME on day four, Tuesday 27 December.

Energetic Particles / Solar Radiation: The high energy (greater than 10 MeV) proton flux is expected to remain at Background levels throughout.

High energy (greater than 2 MeV) electron flux is considered low confidence for the period due to corollaries of the uncertain geomagnetic forecast. Flux is expected to rise due to recent and expected fast wind enhancements, perhaps reaching High levels on diurnal peaks, but any CME influence could dent this. The associated 24-hour electron fluence is Expected to be below the Active ($1e8$ integrated pfu) threshold initially, but with a rising trend, giving a Chance of rising above the threshold for a time, probably peaking day 3, Monday 26 December prior to the main CME arrival.

Figure 1. Solar Analysis Valid 24/0715UTC.



Key: Filament —, Prominence —, Magnetic Field Line - - -, Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α - β - γ - δ and Zurich-McIntosh Axx etc.

Geomagnetic Storms:

The CME forecast is in a state of flux, and the daily risk probabilities are subject to change. The current most likely scenario comprises a possible glance from a pre-existing 21 December CME over the remainder of day one, Saturday 24 December. This serves to prolong the risk of Active or perhaps G1 intervals in the incumbent fast wind of CH56/+, which now appears to be waning (in terms of IMF magnitude, if not solar wind speed).

There then follows up to two further CMEs: firstly that emitted at 24/0230UTC, with many MOSWOC Enlil ensemble members having hits around the middle of the UTC day of Monday 26 December. The second from 23/2330UTC is lower confidence, however a weak arrival in the UTC day of Wednesday 29 December is possible. Complicating the above is the fast wind from CH57/+, which is due 26 December but is much-changed compared to its last outing, and was hitherto expected to be weaker than last pass.

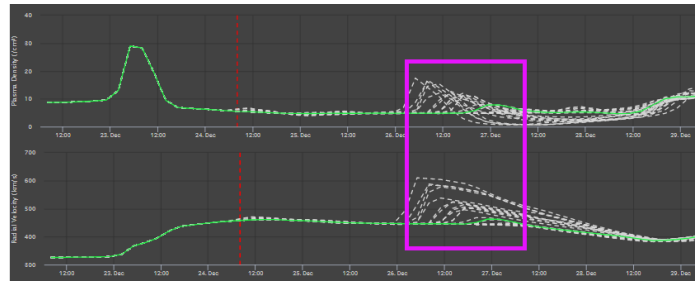
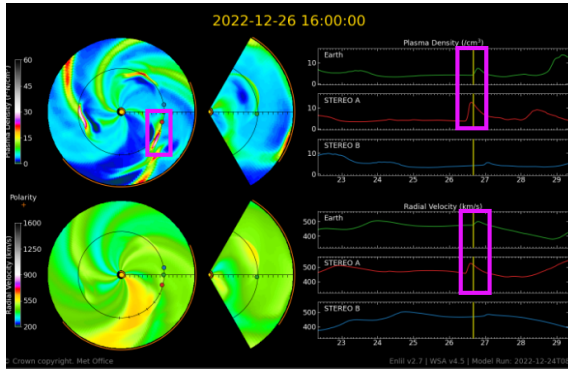
All considered, at present there is a Chance of G1 from the combination of CH56/+ and the 21 December CME over the remainder of day one, Saturday 24 December. A lull should then follow on 25 December, perhaps the most reliable of the four days, before the possible combined effects of CH57 and the 24/0230UTC CME on Monday 26 December. Because of the moderate speed involved and its visually energetic departure from the disc in H-Alpha imagery and AIA304, this may present a risk of G2, rated at a Chance, with G1 Likely. Effects from both the fast wind and the tail of the above CME should be ongoing on the final day of the period, albeit with reduced intensity.

Geo-Magnetic Storm	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Minor or Moderate	G1 to G2	Yes	25	5	60	25
Strong	G3	No	1	1	5	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
21/1127	Partial	AR3169	NE	500	Remainder of 24 December	Small chance glance.
24/0545	Partial	Filament	NE	1235	Second half 26 December	May combine with CH57 CIR
24/0838	Partial?	Filament	S Centre	311	29 December?	Low confidence, awaiting imagery

Figure 2: 0800UTC MOSWOC Enlil run showing the 24/0230UTC northeastern solar quadrant filament eruption boxed in magenta. The deterministic run shows a marginal interaction with this CME, however there are significant number of members with fuller hits. The tail of risk of G1/G2 extends into 27 December as shown, perhaps aided by any CIR preceding CH57/+. The 21 December and 23/2330UTC CMEs are very minor players in the below model run.



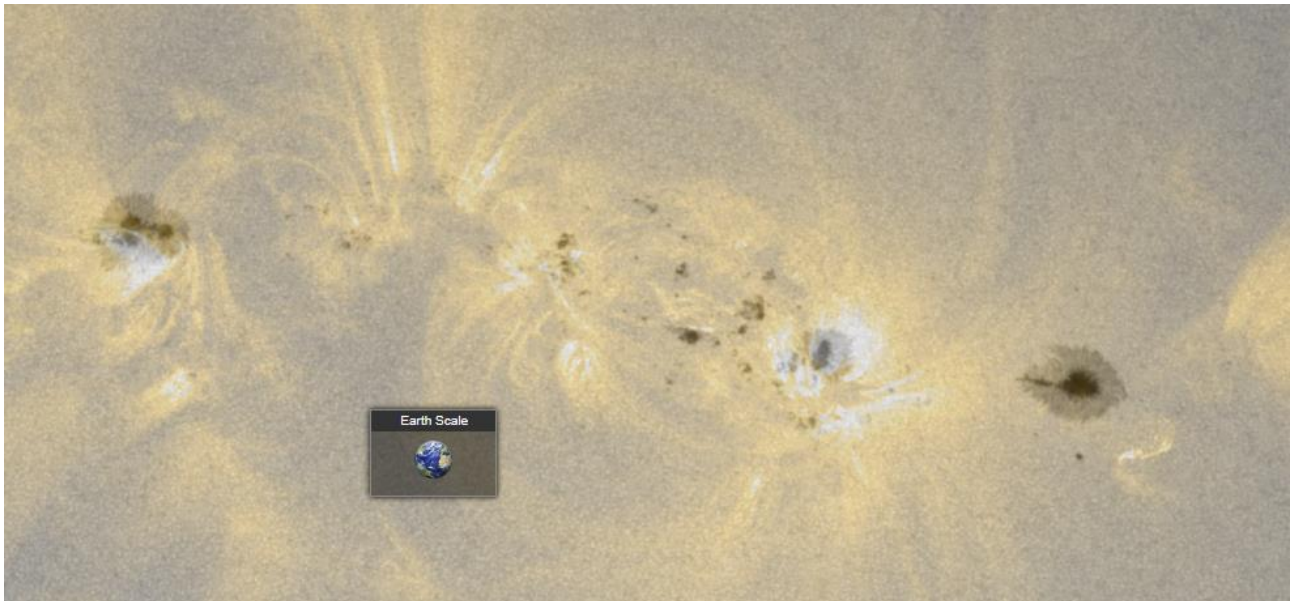
Radio Blackouts - X-Ray Flares:

Solar activity has been Low, but there is now an increased daily Chance of Moderate activity as a result of the recent development of AR3169.

In terms of the balance of regions on the front side, there are no major departures due in the four days. Around midweek, far-side soundings suggest that there may be a large region due. The outlook is therefore for increased activity from around the middle of the coming UTC week, however the degree to which this occurs remains to be seen.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	No	25	25	25	25
Very Active	R3 to R5 X Class	No	1	1	1	1

Figure 3: Helioviewer.org-generated composite image of HMIIF and AIA171 from 24/1200UTC showing AR3171 (spots to left of Earth (included for scale); and AR3169. Almost all of the central trailing spots have developed in the past 24 hours.



Solar Radiation Storms - (High Energy Protons):

The high energy proton flux (greater than 10 MeV) is expected to remain at Background levels. Forecast probabilities have been raised a little relative to recent guidance, due to the westward advance of developing AR3169, although there is as yet no enhancement observed at GOES16 from any flare activity from this or any other spot group.

Radiation Storms	Level ($\text{cm}^{-2} \text{sr}^{-1} \text{s}^{-1}$)	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	$\geq \text{S1}$	No	5	5	5	5
Very Active	$\geq \text{S3}^*$	No	1	1	1	1
* S3 $\geq 10 \text{ MeV} \geq 1000 \text{ pfu}$ and / or $\geq 50 \text{ MeV} \geq 10 \text{ pfu}$. (pfu = $\text{cm}^{-2}\text{sr}^{-1}\text{s}^{-1}$)						

High Energy Electrons Event ($\geq 2\text{MeV}$):

High energy (greater than 2 MeV) electron flux is currently following a low diurnal oscillation at Normal Background to Moderate levels. The forecast as a whole is low confidence, both due to changes in the geometry of CH57, but also because of the presence of CMEs in the forecast.

The current most likely scenario is an upward reaction later in the current UTC weekend from the current fast wind from coronal hole 56, with diurnal peak flux likely reaching High on 25 December. This may then manifest as Active 24-hour integrated fluence into Monday 26 December, depending upon the timing and strength of any enhancement from CH57 which is then due. The most significant complication to this is then the possibility of a CME from 24/0230UTC passing 1AU. Should this occur it will very likely compress the Van Allen belts and delay any eventual rise in flux and fluence, perhaps quashing any rise entirely by re-distributing electron populations.

The associated 24-hour electron fluence is forecast to see a rising trend, with a Chance of rising above the Active threshold by day 3 Monday 26 December, before possible suppression.

GEO Electron Environment	Level ($\text{cm}^{-2} \text{sr}^{-1} \text{day}^{-1}$)	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	$\geq 2 \text{ MeV}$ $\geq 1 \times 10^8$	No	5	20	40	20
Very Active	$\geq 2 \text{ MeV}$ $\geq 1 \times 10^9$	No	1	1	1	1